years ago and have been directing others since then. The joy of discovery doesn’t even have to come from work in my laboratory; reading a great paper in the literature is a thrill of which I never tire. So, I come to global science topics as a working scientist but a rank amateur when it comes to internationalism. However, I feel deeply that a scientist must go beyond his pleasure in his personal science and take some responsibility for the larger issues of the field.

And so I did a little globetrotting last year. Most memorably, I went to Rwanda and India. The contrast between these countries is striking. One is a tiny country, with 8 million closely packed people; the other is a sprawling nation with a billion people. One is still deeply underdeveloped but emerging sprightly from the unimaginable hell of genocide; the other is an established and vibrant democracy on an economic takeoff platform. What I saw in these two countries led me to believe that liberating the spirit of entrepreneurship is a key to economic development. People are the same around the world; free them and they start expressing their individual creativity. I saw the beginnings of that liberation in Rwanda (see sidebar). There is no doubt that in India, as in China, the liberation is in full swing.

**Strengthening Science at Home and Abroad**

In beginning a more general consideration of science in the world, I must admit to an apparent contradiction. We as scientists, engineers, and technologists generally believe that our professions know no borders. We read the literature to gain knowledge, independent of where the experiments were done. We travel to meetings all over the world, sharing our knowledge with anyone who wishes to listen. During the Cold War, we met with our Russian colleagues when we could, ignoring the headlines that made them out to be our enemies. The Pugwash movement, honored with the 1995 Nobel Peace Prize, was an embodiment of that world view (3). A good idea is a treasure, no matter what mind conceives it. The stronger world science is, the more ideas will bubble up, and the richer will be the brew of ideas and experiments that each of us can draw upon.

That is one side of the picture; the other is that we want our own countries to be strong. As an American, I will present this argument from our point of view, but it is equally applicable to any nationality. Our economic health, our security, our ability to live fulfilling and peaceful lives depend on America maintaining a strong base in science and technology. And America remains strong today. But we see that strength slipping and it worries us. The U.S. National Academy of Sciences embodied these worries in its report *Rising Above the Gathering Storm* (4). It is a highly nationalistic document, one that resonated with the science and education communities. It calls for programs to strengthen U.S. science so that we can compete in the newly global economy. By implication, strengthening foreign science would appear

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**Challenges and Prospects of Advancing Science and Technology in Africa: The Case of Rwanda**

Paul Kagame, President of the Republic of Rwanda

I was delighted to participate in the 2008 Annual Meeting of the American Association for the Advancement of Science and have the opportunity to highlight Africa’s and Rwanda’s challenges in using the power of science and technology to transform our societies. I believe that all nations must relentlessly build world-class knowledge institutions that create a robust stock of scientists and researchers, foster a dynamic private sector in which industries nurture innovative talents for prosperity creation, and establish professional public services managed by insightful policy-makers who actively promote science and education.

There can be no better inspiration than the United States. What we seek to achieve in Africa and in Rwanda is what is taken for granted in the U.S.: the continuous expansion of knowledge and innovation that lead to even greater prosperity through a triangular relationship between government, business, and academia. This multifaceted relationship is evident in the entire value chain of education from elementary school to tertiary level, and subsequently to the transfer of skills and knowledge in industry and workforce.

How, then, are we in Africa to create an environment that encourages the harnessing of science and education, which in turn permits a more rapid socioeconomic transformation? More specifically, what socioeconomic development choices have we made in Rwanda, and how are we progressing in utilizing education and science to achieve them?

The challenge on our continent is that each of the three players—government, business, and the university—has yet to consolidate their roles into an interdependent relationship that links demand and supply of scientific and technological innovations on a scale needed to transform our societies. This partly explains why Africa remains impoverished and trapped in the trading of raw

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**Cultivating science.** For countries such as Rwanda, training in science and technology can help build economies and lift people out of poverty.

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government dictation of the directions of science. Recently, the United States has seen how a government can attempt to suppress uncomfortable scientific knowledge when it dislikes the policy implications. Remember, in most countries of the world, governments control academic and research institutions. I will come back to this point.

Science Around the World
Science fits into different countries in different ways. In the United States and Europe, it is an established part of the culture and a generator of economic progress. In the United States especially, we have built commercial engines of innovation around our science and have a highly developed process for funding that innovation. In China, science is venerated and a rapidly growing enterprise, but it is still immature. In India, it is venerated and has an impressive history that is undergoing a renewal. In Africa, practicing science at almost any level is mainly a dream, but in certain countries, the dream is part of the plans for the future. Small countries aspire to having great science but are unable to produce a critical mass unless they import a significant fraction of their scientists. Israel, strikingly, shows that it is possible to keep the flow of scientists and engineers coming in spite of a small population.

For all the differences of how science is practiced in different places and how it affects different countries, there is one constant. It is that basic science is funded by governments. It may be done in research institutes or in universities, it may be funded through institutions or directly to scientists, but it is a governmental activity because only governments have both the funds to afford it and the desire to support it. Poor countries therefore do little; rich countries can choose. In developing countries, there are limited funds and their investment becomes a matter of values. Private enterprise does a lot of applied science, and its research is often the proximate work that spurs innovation, but I believe that it is basic science that makes the leaps that produce the breakthrough concepts. The funding of basic science through investigator-initiated grants is America’s secret weapon.

American science, although largely government-funded, is actually a bottom-up entrepreneurial activity. The institutions of science are largely not governmental—even the state universities are no longer mainly funded by the states. The practitioners are employees of the institutions but they get their funds through individual initiative. Tenure is a wonderful guarantee because it enables each scientist to run an individual program, to decide who to involve, who to collaborate with, how big an operation to run.

In the last few years, I have had occasion to visit many places around the world and have had at least a cursory look at their biological sciences activities. I’ll begin with China and India. Together they represent almost 50% of the world’s population, so what they do is of overriding importance. They are very different places.

China is a totalitarian country, which we should not forget. They may have a free market of commerce, but science is funded by the government, and the government, including the country’s communist party, makes decisions. They decide where to build new universities, how much funding to distribute, where to send funds, and the priority that individual programs should have. The notion of a free market for doing science has not penetrated. There is a place for personal initiative, but the heavy hand of government dominates. They are involved in a huge expansion, but they score poorly on Baltimore’s rules of scientific development.

India is a most interesting place. It has a great tradition of science, which was seeded under British rule and was carried forward by Nehru. However, it has fallen into mediocrity, and bright Indians have been traveling abroad, where opportunity is greater. The country is now committing itself to building strength in basic science. It is growing at an apparently sustainable 9% per year, spinning off huge resources for institutional development. India has a few pillars upon which to build: some fine existing institutions; a remarkable knowledge-based industry, mostly in the information technology area; an impressive generic pharmaceutical business; and a government commitment to building strength in education and research through new institutions. They understand quality and want it; whether they can stick to Baltimore’s rules will be interesting to watch.

“American science, although largely government-funded, is actually a bottom-up entrepreneurial activity.”

—DAVID BALTIMORE,
CALIFORNIA INSTITUTE OF TECHNOLOGY

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materials and natural resources, thereby transferring the more wealth-creating aspects of a value addition to developed countries. Innovative companies fail to emerge due to the low level of domestic processing. The government’s role in promoting education and science both in industry and knowledge institutions remains feeble. Meanwhile, African universities have become almost irrelevant to our socioeconomic development, resulting in perpetual decline and brain drain as capable scientists and professionals leave the continent for better opportunities. The point here, however, is not to lament this condition, but rather to share with you what we are doing about it in Rwanda.

Let me first acknowledge that, in our country, we have neither a dynamic private sector that constitutes a strong demand factor for science and technology, nor strong knowledge institutions to meet such a demand. We do have, however, a developmental vision and a commitment to achieving it. Over the past 7 years, we have been laying the foundation for education and science to play their rightful roles in realizing our goals. As the strongest of the actors in development, Rwanda’s public sector will continue to play a leading role for some time, while other pillars gain strength. Our modest progress in building this foundation may be summarized as follows:

First, we believe that “business as usual” in terms of depending on an economy based on raw material exports will merely entrap us into poverty. We must transcend this mindset and practice. With our objective of becoming a middle-income country by the year 2020, we reasoned that not only would we have to modernize our agriculture for value-added exports, but also to enter “nontraditional” economic niches, such as finance, high-end tourism, and the information and communication technologies (ICT) sectors.

Second, we concluded that Rwandans themselves constitute our principal national asset. We therefore had to refocus our education so that it can provide the people with the requisite skills and knowledge to become a viable multifaceted human capital. That is why we have consistently increased our education budget; about 25% of our national budget now goes to formal and nonformal education, constituting the largest single component of Rwanda’s annual expenditure.
tional morality, and a concern for worldwide development. It will be the tension of economic competition, not the threat of a military strike, that will keep the world stable and peaceful in the future, and we need to focus on the leadership role we can play.

Science in Less Developed Countries

Thus far, our major focus in discussing science has been its role in driving economic development in the developed and developing world. But how about the truly needy countries, the ones where development has yet to make much of a dent? Nongovernmental organizations (NGOs) have generally felt that the needs in these countries are so pressing and so basic that aid should concentrate on their immediate needs, not on high-tech science. But a number of thinkers disagree. At the 2007 AAAS annual meeting, Mohamed Hassan, executive director of the Academy of Sciences for the Developing World, spoke of the leadership role we can play.

Science is a growing enterprise in China, but government funds and decisions rather than personal initiatives dominate its practice. Growing (like Brazil, China, India, Malaysia, South Africa, Turkey, and others) are investing in science and technology, creating a multipolar world of science. These are countries with a strong base, positive growth rates, and increasingly replete government coffers. They can afford to build research facilities. But they all had traditions of research and education as well as institutions to build upon. Sometimes these date from their colonial period. The African countries have much less, and even when their colonial masters built universities, periods of ruinous dictatorship and wars left the institutions in a shambles. Many are now trying to rebuild.

There needs to be an emphasis on institution-strengthening in Africa. Africa needs research, but perhaps a greater need is more trained people. People trained in science and technology can contribute in many ways to economic development. And Baltimore's rules apply. Thus, the institutions that are built should combine teaching and research. It is important to start small, concentrating available resources and talent until such time as there are sufficient trained personnel for further expansion. International institutions within Africa would be best, but it may be too much to wish that African countries...
An Admission and a Wish

In concluding this essay, I want to say something very difficult. I don’t know if I speak for just myself or for many readers. Since 2001, I have lived a life of denial. I have denied responsibility for the actions of America. I have denied that President Bush speaks for and represents my country. I have held my breath, awaiting new inhabitants of Washington who will again be the moral, thoughtful, balanced people who are the true Americans.

But do I have that right of denial, the right to pretend that American actions are not about me? Mustn’t I take some responsibility because our government is a creature of the democracy we cherish? Forcéd by the president, the Congress this year accepted a budget that does not meet the needs of America but there was no uprising by the people. We accepted the right of the president to starve our scientific enterprise: We can only complain, not change the result. Denial is wonderful. We tell ourselves that we travel as people, not as representatives of our country, when in fact we should travel with our head held low, doing penance for the horrors inflicted by our country at Abu Ghraib, at Guantanamo Bay, and in secret jails in eastern Europe. I am old enough to remember going to Europe in 1960 when we were so proud to be Americans, when we could still bask in the reflected glory of the gift of victory we gave the world in World War II. What a long time it has been.

But I have a hope for the future. I hope that when Jim McCarthy takes the reins as the next AAAS president, he will be able to bring a message of optimism. Optimism that our country is prepared to once again act morally, no matter what the provocation; optimism that we will face up to our responsibility to posterity to seriously deal with global warming; optimism that we will reinvigorate our investment in our future, rising to meet the gathering storm; optimism that the tide of religion-based anti-intellectualism that has gripped our nation is being turned.

Then we can reassert our belief in America once again. We can move from denial to pride. We can hold our heads up high as we travel the world, knowing that our fine democracy has once again produced leadership worthy of our great country.

Is this too much to ask, I wonder.

References and Notes

2. Science Debate 2008 worked with Scientists and Engineers for America, the AAAS, the National Academies, the Council on Competitiveness, and other organizations to craft the top 14 questions the candidates should answer. Their answers can be found at www.sciencedebate2008.com/www/index.php?id=42.
3. The 1995 Nobel Peace Prize was jointly awarded to Joseph Rotblat and to the Pugwash Conferences on Science and World Affairs, for their efforts to diminish the part played by nuclear arms in international politics and, in the longer run, to eliminate such arms. Today, the Pugwash mission is to bring scientific insight and reason to bear on threats to human security arising from science and technology, and particularly the threats to humanity posed by nuclear and other weapons of mass destruction (www.pugwash.org/).
6. The Grand Challenges in Global Health Initiative aims to address the health problems that disproportionately affect the world's poorest people and was built on the assumption that with greater encouragement and funding, contemporary science and technology can remove some of the obstacles to more rapid progress (www.gcgh.org/Pages/default.aspx).

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A global perspective. Innovation fueled by a strong science and technology base is as crucial for developing countries as it is for the rest of the world.
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